Successful Cardiac Rehabilitation in Pediatric Patient after Percutaneous Balloon Mitral Valvulopasty: Case Report

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Abstract: ***Background**: Mitral stenosis (MS) is the most common sequelae of chronic rheumatic heart disease (RHD). MS usually presents clinically with exertional dyspnoea anddecreased exercise tolerance. Percutaneous mitral balloon valvuloplasty (PMBV) is the treatment of choice in patients with MS. Nowadays, there is an increasing focus on rehabilitation efforts for paediatric patients who have cardiovascular disease and undergo cardiac intervention, including PBMV. **Case Illustration**: A boy, 13 years old, suffered signs and symptoms of right heart failure and had very limited physical activity. He was diagnosed as severe MS due to RHD and then referred to National Cardiovascular Center Harapan Kita (NCCHK) for further management. He underwent PBMV and continued phase I &II cardiac rehabilitation in Cardiac Rehabilitation Clinic of NCCHK. After finishing his phase I &II cardiac rehabilitation, patient showed increased functional and aerobic capacity. His functional capacity was 12.93 METs and predicted VO2 max was 45.25 mL O2/kg/min. Then, he was recommended to do phase III cardiac rehabilitation with FITT - VP principle at home. **Summary**: Cardiac rehabilitation increases both functional and aerobic capacity in pediatric patient after PBMV*

Keywords: Paediatric, Cardiac rehabilitation, Percutaneous Balloon Mitral Valvuloplasty, Mitral stenosis

1. Introduction

Rheumatic heart disease (RHD) remains an important preventable cause of cardiovascular mortality and morbidity, particularly in low - income and middle - income countries. In 2015, it is estimated there was 1.18 million cases of RHD in Indonesia.1Sequelae of chronic RHD involves damage of cardiac valves. The mitral valve is involved in nearly all cases of RHD.2Therefore, mitral stenosis (MS) is the most common form of sequelae of chronic RHD. MS usually presents clinically with exertional dyspnea and/or decreased exercise tolerance.3Nowadays, percutaneous mitral balloon valvuloplasty (PMBV) is the treatment of choice in patients with MS who have severe MS, pliable, noncalcified mitral valves, symptomatic, absence of left a trial thrombus and absence of moderate to severe mitral regurgitation.4

Children with cardiac disease have not only risk of neuro-developmenta & socio-emotional maladjustment, but also decreased physical health & activity level. Nowadays, due to advanced medical and surgical care, the survival rate of children with cardiac disease has been improved, including them with severe MS who undergo PBMV. As a result, there is an increasing focus on rehabilitation efforts for these patients, in order to improve both their physical well - being and their psychosocial adjustment.5In addition, many studies conclude that exercise training may improve peak VO2 in children and adolescents after congenital heart disease surgery and this should be considered for inclusion in cardiac rehabilitation.6

2. Case Illustration

A boy, 13 years old, came to Cardiac Rehabilitation Clinic of National Cardiovascular Center Harapan Kita (NCCHK) at15th January 2020. He just underwent percutaneous balloon mitral valvuloplasty (PBMV) at 3rd January 2020. Previously, he was diagnosed with severe MS, mildMR, severe PR, mildAR due to RHD and PH. At his last hospital admission in NCCHK, he was hospitalized for about 48 days with signs and symptoms of right heart failure Ross Criteria IV. Before admission, he had very limited physical activity since 3 months ago and was referred from Dr. M Yunus General Hospital in Bengkulu with severe MS due to RHD.

On initial assessment, he had no complaint. There was no chest pain, shortness of breath or palpitation. From physical examination, vital signs & nutritional status were BP 82/57 mmHg, HR 80 bpm, RR 18 tpm, SpO2 93%, body height 134 cm, body weight 24.3 kg, BMI 13.5 kg/m^2, waist circumference 69 cm, neck circumference 28 cm and upper arm circumference 13 cm. The conjunctiva was not pale and sclera was not icteric. Cardiac examination revealed normal first heart sound, normal second heart sound, gallop (-) and mid - diastolic murmur grade 2/4 at cardiac apex& pansystolic murmur grade 2/6 at LLSB. Abdominal examination revealed bloated abdomen with minimal ascites. Extremities examination revealed no edema. Other physical examination found no remarkable findings.

The ECG showed SR with first degree AV block, 80 bpm, QRS axis +110°, LAE, PR interval 222 ms, QRS duration 114 ms, ST depression &Tinv in V1 - V4, Tinv in I aVL V5

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- V6, BVH. The echocardiography taken before PBMV showed severe MS with MVA planimetry 0.3 cm^2& MVG 19 mmHg, mild - moderate MR due to RHD (Wilkins score 7), severe TR with TVG 100 mmHg, high probability of PH, good LV systolic function with LVEF 59% (Teicholz), reduced RV systolic function with TAPSE 1.2 cm, moderate PR and mild AR (see Fig.1 Left).

After PBMV, the evaluation echocardiography showed thrombus (-), LA SEC (-), pericardial effusion (-), RA - RV dilatation, good LV systolic function with LVEF 68% (Teicholz), IVS paradox (-), LV D - shaped (-), decreased RV function with TAPSE 1.8 cm, trivial to mild AR, mitral valve post BMV with MVA planimetry 1.1 cm^2, mean MVG 9 mmHg and peak MVG 13 mmHg, mild MR, severe TR with TVG 70 mmHg and iatrogenic ASD L to R shunt with diameter 1.5 mm (see Fig.1 Right).

At phase I cardiac rehabilitation, he could walk as far as 248 meters during 6MWT with maximal heart rate 91 bpm. At initial phase II cardiac rehabilitation, he could walk as far as 294 metersduring 6MWTwith maximal heart rate 93 bpm and do bicycling with load 25 Watt in 10 minute with maximal heart rate 114 bpm & without any symptoms. Then, he continued the exercise program daily. During his exercise program, he did not complaint any problems. He showed good progression during his exercise program (see Table 1). Treadmill report showed that he could walk as far as 2000 m with maximal walking speed 5.1 km/h (see Fig.2).

After he had finished his phase II cardiac rehabilitation program, we did final evaluation with treadmill test with Bruce Protocol. During treadmill test, he reached stage 3 with exercise duration for about 8 minutes and 1 second. Predicted VO2 max can be calculated using this formula: VO2 max (mL O2/kg/min) = 10.716 + (1.334 x Maximal Treadmill Grade) + (5.203 x Treadmill Speed; mph) + (3.494 x Gender; 0 = female, 1 = male) – (0.413 x BMI) + (0.249 x PFA) [7], in which 1 MET is equivalent to 3.5 mL O2/kg/min. From the formula above, he had functional capacity 12.93 METs with predicted VO2 max 45.25 mL O2/kg/min. Then, he was recommended to do aerobic exercise at home as phase III cardiac rehabilitation, with prerequisite warming up for 10 minutes, such as walking (2.4 - 2.8 km/30 minutes) and bicycling (4.85 - 6.45 km/30 minutes) with frequency 4 - 7 times per week, 30 minutes for each session, target heart rate 118 - 132 bpm and exercise load 7.76 - 9.05 METs.

3. Discussion

Cardiac rehabilitation consists of 3 phases, i. e. (1) Phase I cardiac rehabilitation or in - patient setting rehabilitation, (2) Phase II cardiac rehabilitation or out - patient setting rehabilitation, and (3) Phase III cardiac rehabilitation or home - based or community - based rehabilitation. A structured cardiac rehabilitation program can benefit children by increasing exercise response and physical activity as well as improving developmental, cognitive, and psychosocial outcomes.5

In patients with heart failure, the pathophysiological mechanisms involved in the reduction of their functional capacity are multifactorialand include central (cardiac) dysfunction together with maladaptation in peripheral vascular, respiratory, skeletal muscle, and neurohumoral responses. Many studies showed that the exercise training should be considered as efficient method of improving peak VO2 in children and adolescents.6*Douard et al* studied effect of physical training in patient with mitral stenosis after balloon valvuloplasty. They concluded that physical training to restore better physical capacity after percutaneous transvenous mitral commissurotomy with significantly increased in peak VO2 and peak workload (peak VO2: 26.6 ±4.7 vs 21.6 ±3.8 mL/min/kg, p=0001; peak workload: 125.4 ±26.6 vs 108.5 ±23 watts, p=003).8Our patient also showed significant increased distance during 6MWT, i. e.: 248 m at the end of phase I cardiac rehabilitation, 294 m at the start of phase II cardiac rehabilitation and 405 m at the end of phase II cardiac rehabilitation. From this 6MWT result, predicted VO2 max can be calculated using this formula: VO2 max (mL O2/kg/min) = 12.701 + (0.06 x 6MWT distance) – (0.732 x BMI), in which 1 MET is equivalent to 3.5 mL O2/kg/min.9Based on the formula above, there is significant improved VO2 max in our patient, i. e.: 17.7 mL O2/min/kg during phase I, 20.46 mL O2/min/kg during initial phase II and 27.12 mL O2/min/kg during ending phase II. The increased VO2 max in this case can be explained by 2 mechanisms, i. e.: 1) The improvement of hemodynamic due to PMBV. Immediately after successful PBMV, patients with severe MS achieve a higher cardiac output, lower pulmonary systolic pressure and left atrial pressure. After PBMV, NYHA heart function also significantly improved. This hemodynamic improvement persists until mitral restenosis occurs.1[0], and 2) Peripheral adaptations promoted by physical training. Peripheral adaptations occur in arteries, skeletal muscle perfusion and ultrastructure, and respiratory muscle after cardiac rehabilitation improve the peripheral muscle oxygen extraction capacity leading to an increase in peak VO2 and VO2 at anaerobic threshold. The adaptations include increased muscle fiber size, increased number of capillaries surrounding each muscle, increased myoglobin content, increased both number & size of mitochondria, increased mitochondrial oxidative enzymes activity, and increased carbohydrate & metabolism.[11]

Exercise testing is recommended for children who have acquired valvular disease (Class I). Applications of exercise testing in the young are most often related to measurement of exercise capacity, evaluation of known or possible abnormalities of cardiac rhythm, and evaluation of symptoms elicited by exertion. Exercise capacity is diminished in some children or adolescents with heart disease, and measurement is often useful in evaluating subjective limitations.1[2]The Bruce treadmill protocol is commonly employed for this purpose; endurance time is used as an index of exercise capacity. The treadmill speeds used for the higher levels of the Bruce protocol may be too fast for small children. Under these circumstances, alternative protocols or modifications of the Bruce protocol may be employed.1[3] VO2 max is the amount of O2 that the cardiopulmonary system can deliver to the exercising muscles which reflects the capabilities of a patient's

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cardiovascular system. VO2 max varies with age; it tends to increase and reach a maximum during adolescence/early adulthood and to decline progressively thereafter. It also differs significantly between males and females, especially after puberty. Normal values for VO2 peak are also dependent on body size; larger individuals can consume more oxygen than smaller individuals.1[3] There are several formula used for predicting VO2 max in childrenaged 6 - 11 years old and adolescent aged 12 - 18 years old.

Predicted VO2 max in adolescent aged 12 - 18 years old can be calculated using this formula[7]: VO2 max (mL O2/kg/min) = 10.716 + (1.334 x Maximal Treadmill Grade) + (5.203 x Treadmill Speed; mph) + (3.494 x Gender; 0 = female, 1 = male) – (0.413 x BMI) + (0.249 x PFA), in which 1 MET is equivalent to 3.5 mL O2/kg/min.

For children aged 6 - 11 years old, functional capacity is directly proportional to treadmill exercise duration. It is higher in boys than girls, increased as increased age and decreased as increased BMI.1[5] Treadmill exercise duration (in minutes) =12.863 – (0, 271 x BMI) + (0, 456 x Age) – (1, 345 x Gender; 0=female, 1=male)

During treadmill test, our patient reached stage 3 with exercise duration for about 8 minutes and 1 second. Predicted VO2 max can be calculated using this formula: VO2 max (mL O2/kg/min) = 10.716 + (1.334 x Maximal Treadmill Grade) + (5.203 x Treadmill Speed; mph) + (3.494 x Gender; 0 = female, 1 = male) – (0.413 x BMI) + (0.249 x PFA) [7], in which 1 MET is equivalent to 3.5 mL O2/kg/min. From the formula above, he had functional capacity 12.93 METs with predicted VO2 max 45.25 mL O2/kg/minwhich is equal to 50th percentiles of estimated VO2 max (see Fig.3 and Table 2).

Regular physical activity (PA) is needed in order to avoid the detrimental effects associated with sedentary lifestyle in patient with cardiovascular disorder.1[8]This regular physical activity can be done at home as cardiac rehabilitation phase III program. The general recommendations following the FITT principle for physical activity participation and exercise training in healthy children and adolescents are shown in Figure 4.1[9]American College of Sports Medicine (ACSM) also add Volume - Progression (VP) principle beside FITT principle above. A target volume of ≥500–1, 000 MET - min/week is recommended. A gradual progression of exercise volume by adjusting exercise duration, frequency, and/or intensity is reasonable until the desired exercise goal (maintenance) is attained.2[0]Aerobic exercises are defined as any activity that uses large muscle groups, can be maintained continuously, and is rhythmic in nature. According to the American Heart Association (AHA) and the American College of Sports Medicine (ACSM), aerobic exercises should be performed at least five days per week. The options for aerobic exercises are endless and the selection of activities that are fun and/or entertaining to the child. Resistance training is composed of dynamic movements with progressive overload to increase and improve muscular strength. Resistance training is recommended 2–3 times per week incorporating all major muscle groups. For children and adolescents, the goal of a resistance - training program should aim to improve overall body strength with muscular hypertrophy deemphasized.[21]Individuals with moderate or severe mitral valve stenosis and sinus rhythm or atrial fibrillation should only participate in low dynamic and low static types of sport.2[2]Our patient is recommended to do aerobic exercise, with prerequisite warming up for 10 minutes, such as walking (2.4 - 2.8 km/30 minutes) and bicycling (4.85 - 6.45 km/30 minutes) with frequency 4 - 7 times per week, 30 minutes for each session, target heart rate 118 - 132bpm and exercise load 7.76 - 9.05 METs (60 - 70% from predicted patient functional capacity).

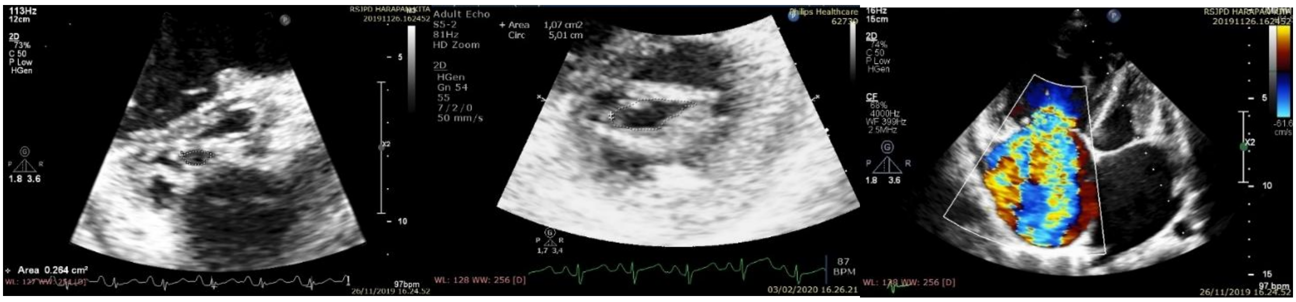
4. Summary

We reported a case of successful cardiac rehabilitation in pediatric patient after PBMV in severe MS due to RHD. At admission, patient came with signs and symptoms of right heart failure and had very limited physical activity. The procedure PBMV improved his symptoms and altered the disease hemodynamic. The phase II cardiac rehabilitation has increased his functional and aerobic capacity. Patient was then recommended to do phase III cardiac rehabilitation with FITT - VP principle at home.

5. Acknowledgements

There is no conflict of interest.

Tables & Figures



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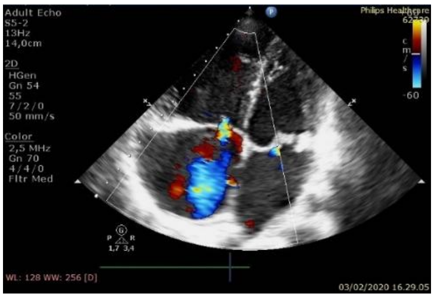

Figure 1: Echocardiography taken before (left side) and after (right side) PBMV. MVA planimetry was increased from 0.3 cm^2 (before PBMV) to 1.1 cm^2 (after PBMV). Tricuspid regurgitation was improved from severe (before PMBV) to mild - moderate (after PBMV).

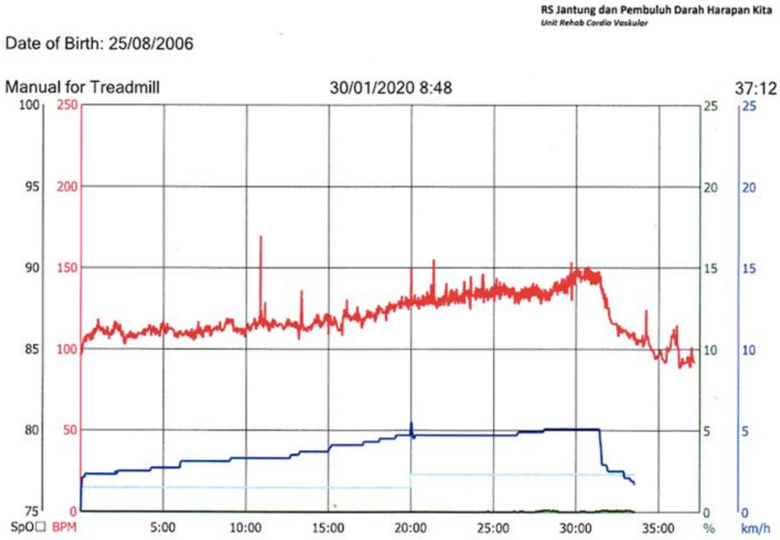

Figure 2: Summary of patient treadmill at day 10 of phase II cardiac rehabilitation. Patient could walk as far as 2000 m with maximal walking speed 5.1 km/h.

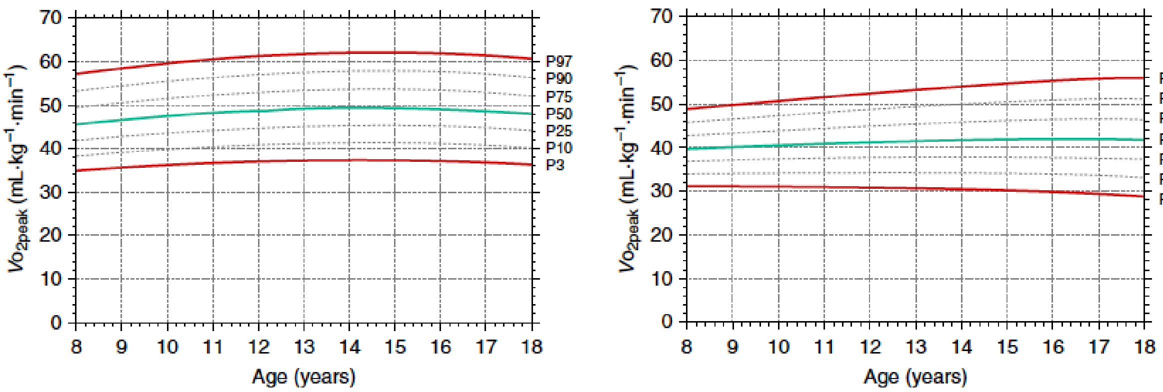

Figure 3: Age - related centile charts for aerobic fitness (VO2 peak/kg) for boys (left graph) and girls (right graph). Green curves show medians and red curves show the upper and lower limits of normal. P = percentile; VO2 peak = highest measured VO2 per kilogram body mass.1[6]

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FITT	Cardiovascular (aerobic) training	Interval training	Muscle strength (resistance) training
Frequency	≥3 times/week	≥3 times/week	2–3 times/week
Intensity	Moderate-to-heavy exercise ($\dot{V}O_{2peak}$ 40—85%)	3–5 min of light-to-moderate baseline exercise ($\dot{V}O_{2peak}$ 20 to 59%) interrupted 6–8 times by 1–3 min bouts of very intense exercise ($\dot{V}O_{2peak}$ >85%)	High (50–70% MVC)
Time	20–60 min	In total 20–60 min	2–3 min per muscle group (about 8–20 repetitions), in total ≥30 min
Type	Running, jumping, cycling, swimming, football	Running, jumping, cycling, swimming	Push-ups, sit-ups/crunches, pull-ups, handgrips, squats, climbing, martial arts, rowing

MVC, maximal voluntary contraction; VO_2, oxygen uptake or oxygen consumption; Interval training can be used alternatively with aerobic training in healthy children.[9]

Figure 4: General recommendations following the FITT principle for physical activity participation and exercise training in healthy children and adolescents[19]

Table 1: Patient progression during phase I and II cardiac rehabilitation

Day	6MWT	Ergo Cycle	1st Walk	2nd Walk	Treadmill	Symptom
Phase I Cardiac Rehabilitation						
I	248 m	-	-	-	-	No Symptom
Phase II Cardiac Rehabilitation						
I	294 m	25 watt/ 10 minutes	0 m	0 m	-	No Symptom
II	-	0 watt/10 minutes	420 m	420 m	-	Fatigue
III	-	10 watt/10 minutes	480 m	480 m	-	No Symptom
IV	-	15 watt/10 minutes	540 m	540 m	-	No Symptom
V	-	15 watt/10 minutes	600 m	600 m	-	No Symptom
VI	-	15 watt/10 minutes	700 m	700 m	-	No Symptom
VII	-	20 watt/10 minutes	900 m	900 m	-	No Symptom
VIII	-	20 watt/10 minutes	1600 m	0 m	-	No Symptom
IX	-	17 watt/10 minutes	0 m	0 m	900 m	No Symptom
X	405 m	0 watt/10 minutes	240 m	240 m	2000 m	No Symptom

Table 2: Aerobic fitness percentiles for adolescents, 12 - 18 years old, based on NHANES (1999 - 2002) [17]

VO2 max (mL O2/kg/min)									
%	**2nd**	**5th**	**10th**	**15th**	**25th**	**50th**	**75th**	**90th**	**95th**
Age (years)	**BOYS**								
12	30, 0	32, 0	33, 9	35, 2	37, 5	42, 3	48, 1	54, 6	59, 2
13	30, 7	32, 7	34, 7	36, 1	38, 4	43, 4	49, 4	56, 0	60, 6
14	31, 3	33, 4	35, 5	37, 0	39, 4	44, 5	50, 7	57, 4	62, 0
15	32, 0	34, 2	36, 4	37, 9	40, 4	45, 7	52, 0	58, 8	63, 4
16	32, 3	34, 6	36, 8	38, 4	40, 9	46, 3	52, 6	59, 4	64, 1
17	32, 2	34, 6	36, 8	38, 4	41, 0	46, 4	52, 8	59, 5	64, 1
18	32, 1	34, 5	36, 8	38, 4	41, 0	46, 5	52, 8	59, 5	64, 1
Age (years)	**GIRLS**								
12	28, 4	30, 0	31, 6	32, 8	34, 7	39, 0	44, 3	50, 5	55, 1
13	27, 9	29, 6	31, 2	32, 4	34, 4	38, 6	43, 8	49, 7	53, 9
14	27, 4	29, 1	30, 8	32, 1	34, 1	38, 3	43, 4	48, 9	52, 8
15	27, 0	28, 8	30, 5	31, 8	33, 8	38, 0	43, 0	48, 4	52, 1
16	26, 7	28, 5	30, 3	31, 5	33, 5	37, 8	42, 9	48, 3	52, 0
17	26, 7	28, 4	30, 1	31, 4	33, 4	37, 7	42, 9	48, 8	52, 9
18	26, 4	28, 1	29, 8	31, 0	33, 0	37, 4	42, 9	49, 2	53, 8

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